Pediatric Traumatic Brain Injury

Proactive Intervention

Third Edition

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Preface

No head injury is too severe to despair of, nor too trivial to ignore.
Hippocrates, 4th century B.C.

Thirty-five years ago we began our journey by conducting research, consulting with individuals who have sustained a brain injury and their families, and supporting service providers. These experiences enabled us to learn and share the wisdom we gained from these experts. We formed interprofessional teams and provided workshops to educate community service providers about kids with TBI and their families.

When we wrote the first two editions of this text, we advocated for a philosophy that would provide services beyond the walls of the medical setting to include reintegration into home, school, work, and community. We recommended that all service providers and families should collaborate throughout the lifetime of the child/adolescent with TBI. We also suggested that technology could aid in the provision of services in all settings. Many proactive approaches we shared are now being implemented in communities. Due to international awareness of brain injury, effective resources, interventions, and technologies that make a significant difference in the lives of youth with TBI have emerged.

We have continued to work with and learn from families and service providers who sought answers to complex questions and requested guidance during stressful situations. We have had the privilege of participating in national think tanks and sitting on national panels where issues, themes, and recommendations for the education of youth with TBI were developed. We have seen these recommendations result in funding opportunities for research and treatment intervention development. We have seen public and professional awareness about TBI increase through articles and reports, such as the CDC's Report to Congress on Pediatric Brain Injury (2018); and with many additional groups and publications focusing on pediatric TBI, youngsters and their needs are being recognized by agencies that can make a difference.

We feel it is an excellent time to update our text because of the many new ideas that emerged in published research, promising best practice reports by service providers who work daily with these children and adolescents, and our additional experiences with this population. *Pediatric Traumatic Brain Injury: Proactive Intervention, Third Edition*, is written for professionals from a variety of disciplines who desire to provide the best supports possible for children and adolescents with TBI. We retained our unique, practical philosophy and theory for planning and implementing programming for this group of youngsters as the foundation. New to this edition are:

updated findings from research, recommendations for services in medical settings and schools, and additional practical strategies and resources that can be personalized for students, families, and service providers. We continue to promote families as integral members of the intervention team. We hope our ideas and recommendations in this updated text stimulate creative problem solving; flexible, functional programs; and interdisciplinary partnerships.

This edition is divided into four major parts and includes 10 chapters. Each chapter begins with an introduction that outlines the objectives for the reader and ends with summary guidelines. The summary guidelines alert readers to key ideas presented in the chapter. We hope the introduction and summaries stimulate practitioners to engage in dialogues with colleagues and families that will result in creative, innovative, and functional interventions for future education and services for students with TBI.

Part I provides an overview of TBI in the pediatric population and outlines our proactive philosophical orientation for assessment and treatment. The first chapter discusses the scope of the problem, including the incidence; demographic characteristics; cognitive-communicative characteristics; and impact on the youngster's life, relationships, and experiences. New information about concussion and return to play and return to learn is outlined. Updates on cognitive communication and social communication that form the basis for working with this population are provided. Chapter 2 presents our philosophical orientation and discusses taking a proactive perspective for assessment and treatment. Processes for proactive planning are explained. We also propose viewing this population from a circle of community interdependence philosophy versus a continuum of care perspective. Chapter 3 stresses the importance of interprofessional collaboration where families and professionals jointly learn from, with, and about TBI together. In Chapter 4, we discuss quality of life and transition issues, building a case for considering these factors when planning and implementing functional service delivery options.

Part II describes how to use problem-solving techniques to conduct functional assessments. Chapter 5 supports an ongoing assessment process and reviews screening and standardized and non-standardized methods for obtaining information regarding the functioning level of the child/adolescent. We present a decision-making tree and interactive communication matrix. The importance of considering the influence of environmental factors on the performance of youth with TBI is discussed in Chapter 6. A process is presented for assessing environmental features and includes practical tools for considering the school and home environments.

Part III suggests functional treatment approaches based on the proactive, problem-solving approach. Chapter 7 outlines general concerns to consider when planning functionally based treatment outcomes and selecting treatment strategies. Outcomes for the specific contexts of home, school, work, and community are provided as models. Examples of functionally based outcomes are included. Information on intervention for discourse development is shared by Sandi Chapman and Lori Cook. Chapter 8 stresses ways significant communication partners, such as family, friends, teachers, and co-workers can be directly involved in treatment. Specific strategies are given. Regardless of the severity of the brain injury, children and adolescents often experience difficulty returning to and staying in school. Chapter 9 discusses problems related to school participation. We make recommendations for assessing the educational environment; making educationally relevant decisions; providing opportunities for students to be educated in the least restrictive environment; and fitting into existing education frameworks such as Multi-Tiered Systems of Support.

Part IV illustrates how to implement our proactive approach. Chapter 10 provides a case example of the proactive responses to problems a child and family experience. Finally, a school reintegration planning guide is included that summarizes the key points discussed throughout the book.

The suggestions in this text are presented in a manner that does not address any specific age group or severity level of injury. Most of the ideas can and should be adapted to fit the unique needs of the individual child/adolescent being assessed and treated. We agree with Hippocrates that there should always be hope, even for the most severely injured, and that there should also be proactive planning, even for the mildly injured.

Acknowledgments

Years ago while working together at The University of Akron, we realized that, although our careers had taken two different paths, we shared a passion for providing high quality services for individuals with cognitive-communicative disabilities. We combined our knowledge and experiences and developed a unique proactive approach for assessing and treating kids with TBI. We embarked on a journey to share our information and along the way met amazing colleagues throughout the world who also were passionate about providing solutions to the challenges that kids with TBI and their families encounter. We could not have written this edition or the first two editions without their research, support, and contributions—their willingness to share ideas, challenge thought processes, write and present collaboratively, and never accept the status quo. Our partnership has resulted in legislative and research initiatives and innovations promising best practices for our children.

This third edition is based upon our previous work and new research in medicine, rehabilitation, and education from colleagues across the world. We elected to keep many of the earlier seminal articles and texts because we believe they form the foundation upon which today's understanding of TBI is built. Without this foundation, today's recommendations would not be pertinent. To that end, we continue to appreciate and honor the work of Vickie Anderson, Sandi Chapman, Linda Ewing-Cobbs, Janet Farmer, Ann Glang, Julie Haarbauer-Krupa, Chris Hagen, Marilyn Lash, Ellen Lehr, Danese Malkmus, Sue Pearson, Ron Savage, Keith Yeates, Mark Ylvisaker, and many others whose work should always be recognized as the shoulders upon which others stand today.

We believe that information about discourse analysis in language is an important issue to include in this edition. Our sincere appreciation goes to Sandra Chapman, Ph.D., and Lori Cook, Ph.D., for writing sections in Chapters 1, 5, and 7 about discourse analysis. They are both researchers and professors at the Center for Brain Health at the University of Texas, Dallas, and they bring a wealth of data, writing, and clinical experience to the topic of discourse analysis in children. They are the best, and now our readers have an opportunity to learn from these experts.

We could never have completed this book without the real experts who have taught us—the families and children and adolescents with TBI who have shared their stories and experiences with us. Their involvement and comments—"We enter into a world no one can truly imagine"; "Please listen to us. She is our child and we know her best"; "We are not resilient. We just get up every day and do what needs to be done"—have shaped our family-centered approach, which guides the assessment and functional intervention segments of this book. We are grateful to the many families who allowed us into their lives so that we might learn and share their expertise and experiences with others.

Particular appreciation goes to Nicole Hodges of Plural Publishing for her patience, planning, and perseverance while we tended to pressing family and life issues and tried to meet deadlines at the same time.

We wish our readers the best of luck on your journey to help children and adolescents who have sustained life-altering brain injuries.

Prologue:
There's No Place Like Home

Oh, Auntie Em, there's no place like home!
The Wizard of Oz (1939 movie)

Dorothy's final words in the classic movie *The Wizard of Oz* have likely evoked strong emotional responses in all of us, as we recognize our need to be in familiar and safe surroundings. A tornado took Dorothy from her surroundings and caused her to become unconscious. Her challenge was finding a way to return to where she had started. She traveled the Yellow Brick Road with friends who were also challenged: searching for a brain, courage, and a heart. Others, such as the Munchkins and the Wizard himself, offered advice, encouragement, and interventions. The helpers wondered if the travelers would find what they sought. The strength to meet inner challenges was found, and they came to the realization that help comes from family, friends, and strangers who can become friends. Dorothy was home. It is instructive to see how often fiction parallels real life. Dorothy could represent any number of children who sustain a traumatic brain injury (TBI) each year. This book focuses on helping children who have sustained a TBI to remain in the security of their homes and communities.

This book is dedicated to our families and friends for their constant love and support.

Paul, Vikki, Samantha, Sydney, Gio & Susan, Dave, Elyse, AJ, Ben
Renick, Megan, Zoey, Asa & Trevor, Jennifer, Xzavier, Lennox, Nixon

We thank you for your moral support, positive reinforcement, and avenues for maintaining a healthy work/life balance and enjoying life's adventures.

To our friends, you know who you are and the distractions and relief you provided!

PART

I

Pediatric Traumatic Brain Injury: Understanding the Problem and Developing a Philosophy of Treatment

> ***Follow the yellow brick road.***
>
> *The Wizard of Oz* (1939 movie)

Meet Mallory, a real-life Dorothy, as she travels the yellow brick road with her friends.

The highway patrolman who first arrived on the scene found two cars totaled and several individuals injured. He was most concerned about Mallory, 16, who was semiconscious and sustained an injury to her head. The girls in the car were from out of state, and the officer spent considerable time during the next few hours assuring the girls and their families that the local hospital would adequately care for them. He worried about Mallory at the time and since has wondered how else he might have helped that day.

The neurologist who treated Mallory in the hospital found that she suffered a depressed skull fracture and cerebral contusions. An intracerebral hemorrhage was noted and surgery completed. The doctor discharged Mallory to return home after 1 week in the hospital. He wonders if she had a complete recovery.

Mallory's family doctor referred her to a local rehabilitation center for outpatient treatment. He relied on reports from parents and therapists and wonders how he could have been more involved, especially now that she is returning to school.

Mallory received speech-language therapy and physical and occupational therapy. The therapists did their best to stimulate all parts of her brain. They were pleased with the advances she made in all areas while she was there but believed there were many other social and cognitive-communicative areas that needed remediation. They wonder how she is doing now that she is discharged to home and school.

Mallory returned to high school without any special planning. Her teachers and guidance counselor are worried that she will not fit in with the other students because she has a head injury. The teachers have never taught a teenager with this medical problem and they aren't sure what special adaptations they might need to provide for this student. They have read the reports from the hospital and rehabilitation facility but are uncertain about the applications of the reports to the educational setting. The teachers and Mallory will need a lot of courage to be successful this school year. They all wonder if this young girl really can learn in the classroom.

There is an employment opportunity for a teenager at the local fast-food restaurant. The manager is aware that Mallory was injured in a car crash and wonders if she is mentally capable of working for him and if she should be offered this after-school job. As he doesn't know much about head injury, he thinks he should pass on hiring her.

Family members are supportive but are upset about Mallory's juvenile behaviors, outbursts, poor organizational skills, inappropriate language, short attention span, and need to talk all of the time. They wonder why she has changed so much and when she will really be back home.

Mallory's friends are embarrassed by her silly talking and poor social skills. They wonder if they should continue to go out with her and what the guys think of all of them these days. They wish they had more heart to put into maintaining a friendship with her.

Mallory's injuries have profoundly affected all who were involved with her. They have been touched by a person who has sustained a traumatic brain injury (TBI) and they will soon learn that Mallory indeed may be affected for a lifetime.

These individuals, like Dorothy and her friends, travel a yellow brick road of challenges. They would like Mallory to come home and function in a world exactly as before the crash. But getting home isn't easy. How they will learn to accommodate to Mallory's strengths and needs; what can be done to aid her in the classroom, at work, at home, in the community; why intervention that is functional in nature is important; and how all of these individuals might have collaborated more effectively is the focus of this book's first four chapters.

From these four chapters the reader will learn to:

1. Recognize the scope of the problem of TBI.
2. Define the incidence, causes, and physiological impact of TBI.
3. Outline the impact of TBI on skills, performance, and behavior in home, school, work, and community.
4. List the cognitive-communicative challenges that can exist after TBI.

5. Describe a philosophy for applying a proactive planning process to developing treatment for a child/adolescent who has sustained TBI.
6. Discuss implications for collaboration and consultation that include professionals from rehabilitation and education, family members, community members, and friends.
7. State quality of life and transition issues for the life cycle.

CHAPTER One

The Scope of the Problem

Introduction

Traumatic brain injury (TBI) in youth presents a public health burden for a population that has a high incidence in medical care and risk for long-term effects that affect lifetime learning and living. The child/adolescent/young adult with TBI is of great interest to a variety of professionals. This interest is stimulated by several factors.

1. Injuries that would have been fatal 20 years ago are now managed by paramedics and trauma teams, with survival from severe injuries increasing annually.
2. Hospital and rehabilitation staff recognize the need to develop programs for children/adolescents that reflect the unique needs of the population. Documentation of treatment approaches and long-term outcomes is demonstrating how and why children can improve after injury.
3. Rehabilitation and educational professionals report that although increasing numbers of children/adolescents have returned to home, school, work, and community, treatment and support services of all facilities have failed to meet the demonstrated needs. Professionals' attention to descriptions of the population and their special needs now provides an understanding of how reintegration should occur. Education of family members, the public, and other professionals has developed a larger pool of persons knowledgeable about TBI.
4. Families and professionals are more likely to advocate at national, state, and local levels for additional services for these children/adolescents because services provided are inadequate to meet the needs.
5. Laws and agency accreditation requirements now identify children/adolescents with TBI as a disability category.
6. Prevention campaigns have increased public awareness of the possible consequences of concussions; drinking and driving; falls; not wearing helmets when riding horses, motorcycles, and bicycles; physical abuse; reckless behavior; and risk taking.

Although these factors continue to provide the impetus for learning about children/adolescents/young adults with TBI, there is still a great need for additional information to be provided to those who can make a difference in these children's lives. For the past several decades, experts in pediatric TBI (Aspen Neurobehavioral Conference, 1999; Dettmer, Ettel, Glang, & McAvoy, 2014; Haarbauer-Krupa et al., 2017; Health Resources and Services Administration, 2001; International Pediatric Brain Injury Society, 2016; McKinlay et al., 2016; Ylvisaker, Todis, et al., 2001) have been brought together to problem solve and make recommendations for international and national research, training, and interventions for youth with TBI. Recommendations from these sources include six areas of continued need:

1. Pre-service and in-service training for service providers who interact with children and adolescents with TBI;
2. Research to determine clear and standardized numbers of children and adolescents injured and in need of intervention in the community;
3. Initiatives that provide data on empirically based interventions for rehabilitation in hospitals, schools, and community that work for this population;
4. Community and agency collaboration for seamless case management and funding of projects;
5. Dissemination of available materials that aid in the understanding of TBI to those who need to understand and deal with it; and
6. Family centered support and intervention initiatives.

These issues provide the impetus for research and intervention for the foreseeable future.

When a child/adolescent sustains a TBI, there are immediate as well as sustained implications for the family and community throughout the life cycle. Because of multiple changes for the family, considerable information must be understood to aid the child/adolescent to develop and learn. Family and community members, peers, and rehabilitation and educational professionals need to recognize and understand the scope of the problem, which encompasses the following:

- Terminology associated with TBI
- Incidence
- Injury severity
- Mechanism of injury
- Laws and accreditation standards specific to this population
- Unique variables of TBI as they apply to children and adolescents
- Potential impairments that can occur as a result of the injury
- Characteristic behaviors that can contribute to difficulty at home, school, or work or in the community.

The remainder of this chapter focuses on developing an understanding of these issues and supporting the international and national recommendations for research and education.

Meet the Hogan Family

It is our belief that we, as professionals, learn much from the families with whom we work. They often provide us with insights, special information, and determination. The Hogan family consists of parents Tom and Sharon and children Jason, Melissa, and Rachel (ages 14, 12, and 10 at the time of Jason's injury). Jason was severely injured when his bicycle was hit by a car. His mother, Sharon, kept a journal of the family's experiences, and she has given us permission to share some of her thoughts with you. Her comments are scattered throughout the book in specially marked areas. She simply says, "I speak from the heart." We hope her comments provide additional insight into the truly unique world of pediatric TBI.

What Shall We Call It? Terminology Associated with TBI

Terms in the literature describing injury to the brain are sometimes used synonymously but have different meanings. Because various terms are employed, some confusion is possible. The following terms along with specific meanings are found in the law or in the literature. Figure 1–1 depicts the relationships of the terms that follow.

Head Injury

Head injury implies damage to any part of the head. It is a broad term that encompasses injury from internal accidents, such as stroke, or external forces, such as a blow to the head. Head injury can imply injuries to the face, scalp, skull, or brain.

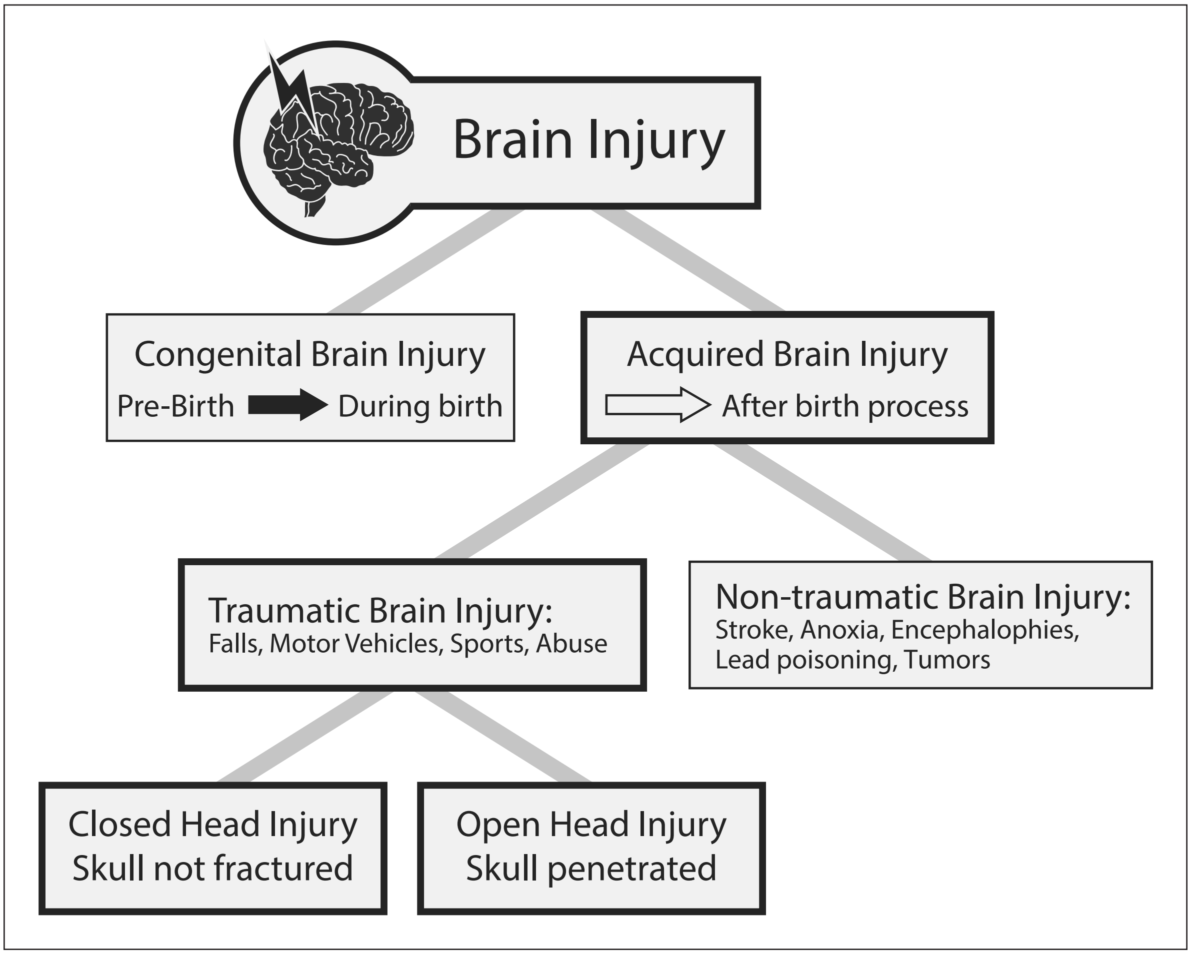

Figure 1–1 Differentiation of various types of brain injury.

Brain Injury

Brain injury is a very broad term that encompasses congenital and acquired damage to the brain.

Congenital Brain Injury

Injury that occurs to the child's brain prior to birth is considered to be congenital. The types of disabilities associated with congenital brain injury are excluded from this text, as the focus is on brain injuries that occur after birth.

Acquired Brain Injury (ABI)

ABI is a general term that includes all types of injury to the brain, both nontraumatic and traumatic.

Nontraumatic Brain Injury

Nontraumatic brain injury is a form of ABI. It can be caused by anoxic injuries, i.e., reduction of oxygen to the brain from anesthetic accidents, hanging, choking, near drowning; infections such as meningitis and encephalitis; strokes; tumors; metabolic disorders such as insulin shock and liver or kidney disease; toxic encephalopathies such as lead poisoning, mercury, crack cocaine, and other chemical agents.

Traumatic Brain Injury (TBI)

TBI is a form of acquired brain injury (ABI). Several definitions for TBI are accepted. What follows is the definition of the federal Division of Special Education, which is in the rules and regulations for Individuals with Disability

Education Act (IDEA, 1992). This definition is the guideline for state departments of education in establishing how states provide educational services to children/adolescents. It is provided because it is applicable to children/adolescents and the services they may require in the public schools. It should be noted that some states have expanded their definition for qualification for services within the category of TBI to include ABI. State departments of special education should be contacted for specific definitions and regulations for placement in this special education category.

"Traumatic brain injury" means an acquired injury to the brain caused by an external force, resulting in total or partial functional disability or psychosocial impairment, or both, that adversely affects a child's educational performance. The term applies to open or closed head injuries resulting in impairments in one or more areas, such as cognition; language; memory; attention; reasoning; abstract thinking; judgment; problem solving; sensory, perceptual, and motor abilities; psychosocial behavior; physical functions; information processing; and speech. The term does not apply to brain injuries that are congenital or degenerative or brain injuries induced by birth trauma (Federal Register, 1992).

TBI generally results in diffuse axonal injury secondary to acceleration forces. This means there can be widespread damage within the cortex that can impair any variety of brain functions in unusual patterns. This damage is at the axonal or cellular level and is often not detected by traditional brain scans. Other pathophysiologic factors that create TBI include direct laceration of neuronal tissue, edema, ischemia/hypoxia, and hemorrhage. Distinctions are made between two types of head injury: open and closed.

Open Head Injury (OHI)

OHI is regarded as an injury in which the brain tissue is penetrated from the outside, as with an obvious wound to the head, such as a gunshot wound or a crushing of the skull. The injury tends to result in localized (focal) damage and somewhat predictable impairments based on localization and degree of damage (Glenn, Sutton, & Hovda, 2017; Jennett & Teasdale, 1981).

Closed Head Injury (CHI)

There is no open wound to the head; damage is caused by a blunt blow to the head or an acceleration/deceleration of the brain within the skull. The injury results in more diffuse brain damage with resultant variable and unpredictable consequences (Glenn et al., 2017; Jennett & Teasdale, 1981).

> We had to see Jason. I was not prepared for the sight I saw that night. My son was gray and looked like a corpse. We felt as if part of our soul had left our bodies. We were asked to leave . . . and wait. Finally, the doctors came out trying to explain what had happened. Jason was in a coma with high pressure on the brain with a "closed head injury." I didn't know what a closed head injury meant until later on in the learning process. (Jason's mom)

Mild TBI/Concussion

Mild TBI (mTBI) is synonymous with concussion. Concussion is defined as "a type of brain injury that changes the way the brain normally works. A concussion is caused by a bump, blow, or jolt to the head. Concussions can also occur from a fall or blow to the body that causes the head and brain to move rapidly back and forth. This sudden movement can cause the brain to bounce around or twist in the skull, creating chemical changes in the brain and sometimes stretching and damaging brain cells. Even what seems to be a mild bump to the head can be serious" (CDC, n.d.).

Concussions can be considered uncomplicated—no overt neuroimaging findings—or complicated—intracranial abnormalities such as contusions or hematomas found on CT scans or MRI (McCrory et al., 2013; Ontario Neurotrauma Foundation, 2013).

Signs of a concussion include dizziness, headache, nausea, vomiting, lethargy, irritability, difficulty concentrating, poor attention and memory, and inadequate social communication. Symptoms resolve in 90% of the injuries within days or several weeks. Ten percent have residuals that can last a lifetime. Implications for children/adolescents with mTBI that do not resolve include inability to learn or organize, poor cognitive-communicative skills, problems maintaining concentration for school or work, psychosocial difficulties, and headaches or dizziness.

In the past decade, public awareness about concussion, especially sports concussion, has increased. Becoming more prominent, especially in the school setting, is the speech-language pathologist's role in concussion prevention and management, including participating in return to play (RTP) and return to learn (RTL) protocols, and treatment for ongoing receptive, expressive language concerns and academic and social learning issues (Halstead et al., 2013; Hotz et al., 2014; Ketcham et al., 2017; Vargo, Vargo, Gunzler, & Fox, 2016).

Additional information about sideline evaluations, RTP, and RTL is available and will be addressed in other chapters (Ontario Neurotrauma Foundation, 2013; Halstead et al., 2013; Sady, Vaughn, & Gioia, 2011).

Moderate TBI

Loss of consciousness (LOC) can be present for up to 24 hours in moderate TBI. Neurological signs of trauma to the brain may include skull fracture, contusions (bruises), hemorrhage (bleeding), and focal damage identified by computerized tomography (CT) or magnetic resonance imaging (MRI). Implications for children/adolescents with moderate TBI include physical weakness, cognitive-communicative impairments, difficulty learning new information, and psychosocial problems. Learning and lifetime living concerns can be an issue for 33–50% of the population.

Severe TBI

The duration of unconsciousness is longer than 24 hours in severe TBI. Multiple cognitive, cognitive-communicative, physical, social, emotional, and behavioral problems can exist for a lifetime for up to 80–90% percent of this population. Special considerations in home, school, community, and the workplace are often required (Haarbauer-Krupa et al., 2017; Pasino, 1996; Ylvisaker & Feeney, 2007).

It should be noted that the terms "mild," "moderate," and "severe" were developed to describe acute care medical conditions. These terms become less clear and less useful after the acute care phase. About 10% of persons with mild injuries may have lifetime impairments. About 15% of persons with severe injuries may return to home, school, and community with minimal concerns. Therefore, no generalization about severity levels and assumptions about long-term treatment and care should be made without knowledge of individual circumstances and impairment levels. Researchers have not confirmed a linear relationship between severity of injury and impact on lifetime of care injuries. However, implications from recent reports (Anderson, Brown, Newitt, & Hoile, 2009; Anderson, Godfrey, Rosenfeld, & Captropa, 2012; Babikian & Asarnow, 2009; Babikian, Merkley, Savage, Giza, & Levin, 2015; Haarbauer-Krupa et al., 2017; National Institute on Disability and Rehabilitation Research, Pediatric Trauma Registry, 2001) are that lifetime learning and living challenges for individuals, families, and community supporters become more difficult and complex with moderate to severe injuries.

Who Are They? Incidence, Severity, and Mechanism of Injury

Incidence

It is difficult to ascertain accurate statistics on the number of children and adolescents who sustain TBI because there are few systematic or universal guidelines developed by trauma centers, rehabilitation facilities, or school systems that provide uniform methods of record keeping. Therefore, counts differ because definitions of trauma vary, methods of reporting are inconsistent, and facilities emphasize different aspects (medical, educational, impact on family, finances, lifetime of care issues) when obtaining data.

However, the Centers for Disease Control and Prevention (CDC) has provided the most accurate information to date. According to the CDC (2018), TBI is a major cause of death and disability in the United States. TBIs contribute to about 30% of all injury deaths (Taylor, Bell, Brieding, & Xu, 2017). Each year approximately 700,000 U.S. children age 0–19 years sustain a TBI requiring hospitalization or emergency treatment (Coronado et al., 2015; Faul, Xu, Wald, & Coronado, 2010). Children 14 years of age and younger make half a million emergency department (ED) visits for TBI annually (Faul et al., 2010). TBI-related ED visits for children occurred at a rate of 889 per 100,000 in children age 5–14 years. Rates of TBI-related ED visits continue to increase. For example, TBI-related ED visits increased for all age groups from 2001–2002 through 2009–2010, rising most for youth 4 years of age and younger, by more than 50% between 2007–2008 and 2009–2010, from 1374.0 to 2193.8 per 100,000. Children 0 to 4 years of age had the highest rates of ED visits for any age group, typically almost twice the rate of those in the next highest age group of 15 to 24 (Taylor et al., 2017). Additionally, in 2012, an estimated 329,290 children, age 19 or younger, were treated in US EDs for sports and recreation-related injuries that included a diagnosis of concussion or TBI. From 2001 to 2012, the rate of ED visits for sports and recreation-related injuries with a diagnosis of concussion or TBI, alone or in combination with other injuries, more than doubled among children age 19 or younger.

Emergency department visits are one source of data for pediatrics, but it does not capture those who do not seek treatment or those who seek treatment in other locations such as urgent cares and pediatrician offices. A recent study examining data in a large health care system reported that 80% of children with concussions were seen for care in pediatrician offices (Arbogast et al., 2016), supporting the need to expand data collection beyond emergency department visits to gain a more accurate estimate of incidence.

Internationally, the numbers of those with acquired brain injury (ABI), continue to grow as well (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusingye, 2007; International Paediatric Brain Injury Society, 2016). This data suggests that brain injuries in children are a growing societal concern around the world.

As data change annually, note that TBI up-to-date data and statistics are available at https://www.cdc.gov/traumaticbraininjury/index.html on the "Get the Facts" page. Several of these datasets are also available for download at data.cdc.gov. Additionally, current concussion data can be accessed at the Concussion Database (cd@drakefoundation.org, https://concussiondatabase.com/).

Injury Severity

Most TBIs are mild and are commonly called concussions (CDC, 2003). Mild traumatic brain injury accounts for 70–90% of TBI ED visits (Cassidy, Carroll, Peloso, & Borg, 2004; Faul et al., 2010). Moderate to severe TBI occurs at a lower rate than mild injuries in children but is associated with worse outcomes. In a cohort study reporting severity from a group of children seeking emergency medical care from hospitals ($N = 2940$), 84.5% had mild TBI, 13.2% had moderate TBI, and 2.3% had severe TBI (Rivara et al., 2012).

Mechanism of Injury

Each year, thousands of children and adolescents sustain central nervous system (CNS) injuries as a result of TBI. Causes of injury include motor vehicle crashes, all terrain vehicle (ATV) crashes, physical and substance abuse, assaults, motorcycle crashes, vehicle–pedestrian accidents, stabbings, and bicycle crashes. TBI-related mechanism of injury shows trends by age, with falls and motor vehicle and sports/recreation accidents as the primary mechanisms of injury for children. Falls are the primary mechanisms of TBI-related ED visits in the youngest (0–4 years), accounting for 72.8% of TBI-related ED visits. Injuries caused by being struck by/against an object (34.9%) and falls (35.1%) account for the majority of injury in youth 5–14 years of age with respect to TBI-related ED visits. For persons in age groups 15–24 years, the proportions of TBI-related ED visits due to assaults, falls, and motor vehicle traffic events are nearly equal within the age group (CDC, 2018). The data reported by the CDC supports information provided in earlier reports. Causes of injury according to age (Bruce, 1990; DiScala, 2001; Mira, Tyler, & Tucker, 1988) included:

- Infants: mishandling by caregivers, including accidental dropping, allowing children to roll from changing tables, and physical abuse
- Toddlers: falls, motor vehicle crashes, physical abuse
- Preschoolers: falls, motor vehicle crashes, physical abuse